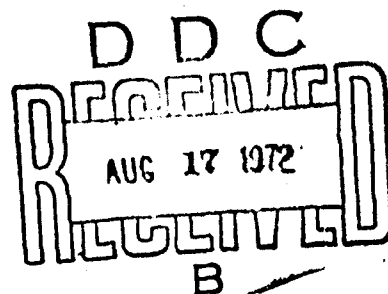


REPORT NO. FAA-FS-600-5

AD 746581

Evaluation of 360° STROBE LIGHTS

D. D. Murphy
Frank Parr



July 1972

FINAL REPORT

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**DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION**

Flight Standards Service
Washington, D. C. 20590

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16. Abstract The Unitron International Systems, Inc. "Visual Vector" 360° REIL and RAIL systems were loaned to FAA for evaluation to determine whether this type of system should be introduced into the NAS. 79 subject pilot questionnaires were recorded for analysis. It was found that: 1. Most subjects considered the 360° systems to be better than the standard RAIL and REIL systems. 2. No spatial disorientation occurred due to the light systems. 3. No blinding effect was apparent when intensity set low night and high day. 4. The systems provided identification and guidance for straight-in, circling, and offset approaches. 5. Night usable distance was over 8 miles in clear weather. Day usable distance was approximately 5 miles in clear weather. 6. Pilot control for on-off was usable. 7. The RAIL/REIL system provides high and low intensity capability. 8. The preferred flash rate is once per second. 9. The combination RAIL/REIL configuration is preferred. 10. The 360° systems provide low visibility guidance. 11. Increased threshold light intensity is desirable.			
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Project Report on an Operational Evaluation of the Unitron
360 Degree Strobe Lights (REIL & RAIL).

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July 1972



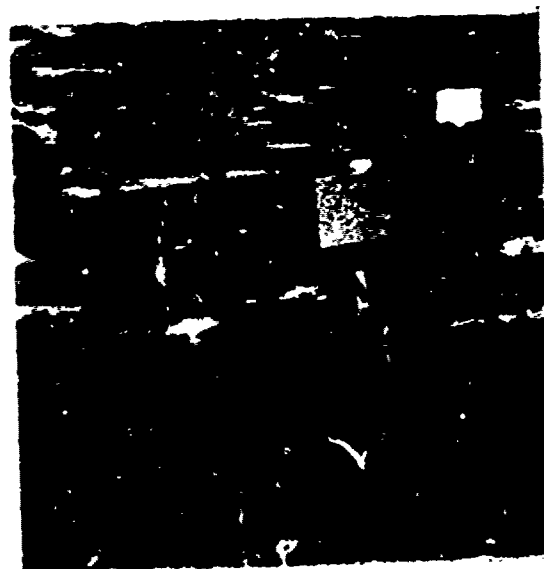


Figure 1. Expressway Junction Airport, Oklahoma City, Ok., Test Site.

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Figure 2. Wiley Post Airport. Test Site.



INTRODUCTION

Union International Systems, Inc., is the manufacturer of the "Visual Vector" REIL and RAIL systems. They have loaned these systems to the Federal Aviation Administration for an evaluation to determine whether the 360 degree type systems should be introduced into the National Airspace System (NAS). The Washington headquarters has assigned the evaluation task to the Standards Development Branch of the National Flight Inspection Division.

The lighting systems are 360 degree strobes. They are designated Models 1600 and 1600E REILs and Model 1400 RAIL.

The 1600B REIL consists of two fixtures, one of which is placed on each side of the runway at the threshold. It has a fixed intensity of 2500 candelas and flashes at the rate of once per second.*

The 1600 REIL also consists of two fixtures, one of which is placed on each side of the runway at the threshold. However, it features a variable intensity. High intensity is 6000 candelas and low intensity is 1200. The tested lights had a capability of being set to flash at once per second or twice per second.*

The 1400 RAIL consists of a minimum of five light fixtures. They are set up along the extended runway centerline. Like the 1600 REIL, they have a variable intensity of 6000 or 1200 candelas and the tested system could be flashed at once per second or twice per second.*

All systems may be set up to be controlled by the pilot by wiring in a receiver-controller similar to that unit meeting FAA Specification L-854.

In comparison, strobe (condenser discharge) lights specified for use in the standard REIL and RAIL comply with Specification L-849, which requires that their intensity at peak beam be 10,000 to 17,000 candelas with 5,000 candelas output over the 25 degrees of beam spread. They have no intensity control capability.

* Intensity values are 'as stated' by manufacturer.

STATEMENT OF THE PROBLEM

The FAA does not list a 360 degree REIL or RAIL system. No listing exists either for a variable intensity REIL or RAIL. An operational evaluation was requested to determine whether these systems should be included in the NAS.

OBJECTIVES

Specific objectives of the project were as follows:

Model 1600 and 1600B REIL Systems.

Determine whether these systems will provide rapid and positive identification of a runway or landing area:

- a. From 360 degrees around the lights.
- b. When surrounded by other lights.
- c. During straight-in and circling approaches.
- d. Without spatial disorientation to pilots.
- e. Without blinding effect on pilots.

Model 1400 RAIL System.

Determine whether the system will provide runway alignment information:

- a. During straight-in, offset, and circling approaches.
- b. Without spatial disorientation to pilots.
- c. Without blinding effect on pilots.

Determine the desirability of the variable intensity feature of the system.

Determine the feasibility of the pilot having control of the lights from the cockpit.

Determine which of several configurations of RAIL, RAIL/REIL, RAIL/T-bar, LDIN, etc., is the preferred configuration.

Determine the preferred spacing of RAIL light units and the effect of irregular spacing (if terrain features prevented regular spacing installation).

Determine the preferred flash rate; once per second or twice per second.

METHODOLOGY

The general plan was to install the test equipment at airports in the Oklahoma City area and have subjects observe the lights during approaches. Expressway Junction airport, north east of the city, was selected as the test site for the Model 1600B REIL. Wiley Post airport, northwest of the city, was chosen for the RAIL and Model 1600 REIL. The runway selected at Wiley Post was 17L.

Subjects included pilots, engineers, and lighting experts. Pilot experience ranged from 16 to over 13,000 flight hours. Certificates of subject pilots included student, private, instrument, commercial, and airline transport ratings. Some were civil pilots, others were military.

Interviews were recorded after day and night flights. 39 runs were made at Expressway Junction airport and 40 at Wiley Post airport. Each subject viewed both the REIL and RAIL at Wiley Post. Weather was VFR, sometimes with haze, except for 1 IFR flight at Wiley Post. Additional flights were therefore made during IFR weather at Wiley Post to evaluate the strobes under reduced visibility. These special flights were made in fixed wing and rotary wing aircraft.

Subjects were encouraged to make any voluntary comments they wished after their flights.

Special video tape reports were filmed at the Wiley Post airport to show the 360 degree capability of the REIL/RAIL, and to compare the test system with the standard MALS/RAIL.

For the evaluation of the Model 1600B REIL at Expressway Junction, the light units were placed approximately 20 feet off the side of the runway edge. Tests were run with the lights at the north end and at the south, depending upon wind direction. The south end of the runway lies in an area with many other lights, including expressway arc lights, flood lights, and large illuminated signs. The north end area has little or no other lighting.

The evaluation of the RAIL and REIL at Wiley Post airport involved, in addition to effectiveness, the selection of the best configuration, best flash rate, best light spacing, and an evaluation of irregular spacing of one or more lighting units.

Five light configurations were observed. They included the RAIL only, RAIL and T-bar, LDIN, and RAIL/REIL. Approaches to Wiley Post were made over city lights from the east, and over relative darkness from the west.

Configurations are shown in Figures 3 through 8.

Subjects whose observations were recorded on the REIL, either the Model 1600 at Wiley Post or the 1600B at Expressway Junction were, whenever possible, asked to observe the Runway 12 REIL installation at Will Rogers World Airport in order to compare the standard system with the test systems.

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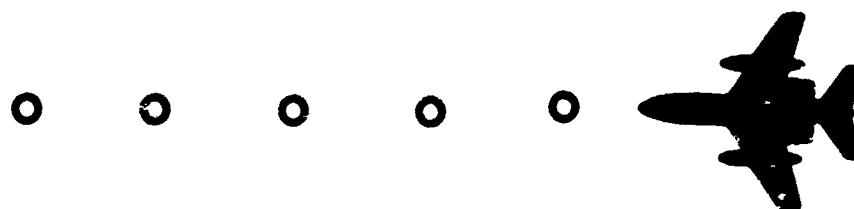


Figure 3. RAIL System Configuration.

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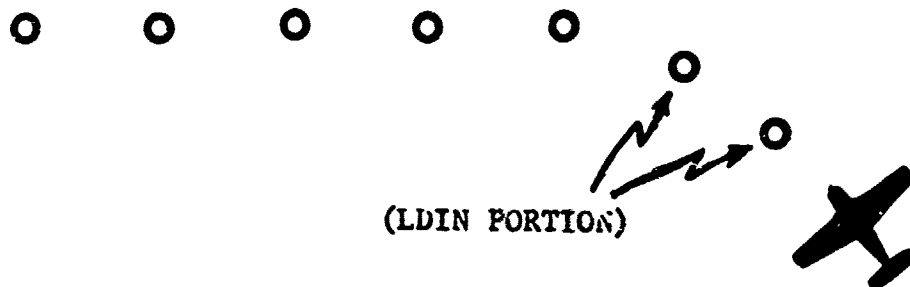


Figure 4. LDIN System Configuration.



Figure 5. REIL System Configuration.



Figure 6. RAIL/REIL System.

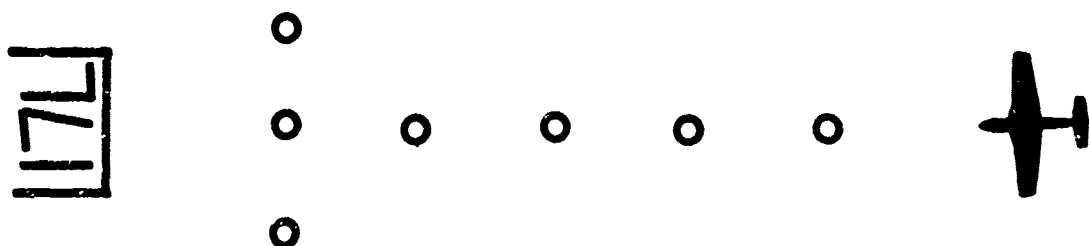


Figure 7. RAIL with Roll Bar.

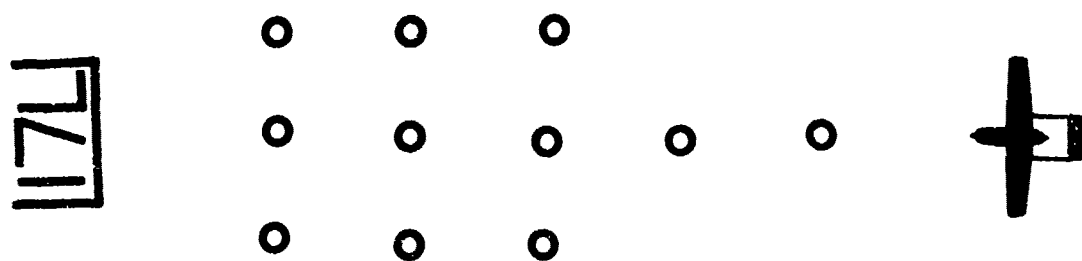


Figure 8. RAIL with 3 Roll Bars.

DATA REDUCTION

Model 1600B REIL - EXPRESSWAY JUNCTION

Summary of questionnaires.

1. Does it assist you in locating the airport ?
YES - 36 NO - 1 NO COMMENT - 2
2. Did it provide you a rapid and continuous 360 degree visual fix to the runway threshold ?
YES - 38 NO - 1 NO COMMENT - 0
3. Did it provide you orientation to the runway ?
YES - 38 NO - 0 NO COMMENT - 1
4. Did it provide you guidance to the runway threshold ?
YES - 39 NO - 0 NO COMMENT - 0
5. Does it override the preponderance of other surrounding lights ?
YES - 38 NO - 1 NO COMMENT - 0
6. Did it provide you assistance on your low visibility approach?
No low visibility approaches were flown at Expressway.
7. Did you find the sequence flashers blinding on the approach ?
YES - 3 NO - 36 NO COMMENT - 0
8. Do you think the flash rate should be increased ?
YES - 1 NO - 36 NO COMMENT - 2
9. Did you encounter any spatial disorientation ?
YES - 0 NO - 39 NO COMMENT - 0
10. Did the 360 degree strobe light blind you while taxiing, during runup, or while aligning for takeoff ?
YES - 0 NO - 38 NO COMMENT - 1
11. What altitude and distance from Expressway Airport did you first observe the lights ?
Night altitude 2000-5000, distance 4-15 miles.
Day altitude 2000-2100, distance 3-6 miles.
12. Have you flown into an airport which utilizes the standard REIL ?
YES - 18 NO - 19 NO COMMENT - 2
If "YES", how do you compare the systems ? Explain under "Comments".

Comments:

"The REIL at Will Rogers appeared somewhat brighter after using the 360° strobes."

"Far superior."

"Equal."

"Better than REIL."

"Provide 360° visibility of lights." (Two subjects)

"The standard REIL was noticeably brighter. However, due to the other superior runway lights associated with the standard REIL it was no more effective than this 360° strobe."

"They seem to be very similar in effect, and as a basic quick runway identification and reference."

"The lights at Wiley Post 17L (test set of standard REIL) were very distracting. These are not as distracting."

"Very favorably."

"Think the new system is better for airport location."

"360° strobe much more effective in quick location of runway end and general orientation."

"This system is not as blinding and is visible from all angles and required distances. I like it much better than the REIL."

"360 system much more desirable. Lower rate of flash is more comfortable, and the ability to sight the runway threshold from 360 degrees is an outstanding aid for locating a runway located among numerous city lights."

"It assists the pilot quite a bit for visual fixes."

"Prefer the continuous (360°) fix to the approach end of runway."

NOTE: See Appendix for additional comments.

DATA REDUCTION

Model 1600 REIL - WILEY POST

Summary of questionnaires.

1. Does it assist you in locating the airport ?
YES - 34 NO - 1 NO COMMENT - 0
2. Did it provide you a rapid and continuous 360 degree visual fix to the runway threshold ?
YES - 34 NO - 0 NO COMMENT - 1
3. Did it provide you orientation to the runway ?
YES - 34 NO - 1 NO COMMENT - 0
4. Did it provide you guidance to the runway threshold ?
YES - 35 NO - 0 NO COMMENT - 0
5. Did they override the preponderance of other surrounding lights ?
YES - 33 NO - 2 NO COMMENT - 0
6. Did it provide you assistance on your low visibility approach ?
YES - 17 NO - 0 NO COMMENT - 16 (No low vis)
7. Did you find the sequence flasher blinding on the approach ?
YES - 2 NO - 33 NO COMMENT - 0
8. Do you think the flash rate should be increased ?
YES - 0 NO - 35 NO COMMENT - 0
9. Did you encounter any spatial disorientation ?
YES - 0 NO - 35 NO COMMENT - 0
10. Did the 360 degree strobe lights blind you while taxiing, during runup, or while aligning for takeoff ?
YES - 2 NO - 31 NO COMMENT - 2
11. What altitude and distance from Wiley Post did you first observe the lights ?
Night altitude 2000-5000, distance 3-10 miles.
Day altitude 2000-3500, distance 5-7 miles.
12. Have you flown into an airport which utilizes the standard REIL ?
YES - 32 NO - 2 NO COMMENT - 0
If "YES", how do you compare the systems ? Explain under "Comments".

Comments:

"Definitely superior at any angle more than 30° from runway centerline."

"The standard REIL are directional and have little value beyond 90° either side of the center of the runway they are aligned to."

"Both systems appear the same and are highly beneficial in both VFR and IFR weather."

"Better because they can be seen from 360°."

"This system is better due to 360° visibility."

"This (is the) way Midway in Chicago (is) with one REIL light (on each side) and this system is far superior."

"Better during circling maneuver. No difference on final."

"Believe it advantageous to have runway end identification for 360° as compared for example with Will Rogers."

"Look the same."

"The 360° lights were as good or better."

"This is of more help in locating the runway."

"If good VFR or not too bad vis, standard system in my view is adequate."

"It is an improvement over standard REIL since it provides a greater visual fix area."

"Favorably. Visible lights from all angles."

"This system seems to be better since it is easier to determine the exact location of the runway by the difference in brightness between the two REIL lights indicating respective distances from the pilot."

"Much better for locating runway."

"The standard REIL is not visible from all directions and is not as good for locating an airport & runway."

"Equal except for the full 360° visibility factor - include this and this experimental system is much superior."

"The 360° strobes are excellent. I was able to locate the runway with no trouble."

"Much more improvement."

"Similar"

"This one is much better due to guidance in all quadrants, gives better orientation to runway in use."

"The difference is in the omnidirectional operation of the 360° REIL."

"The standard REIL is much less effective than the REIL observed at Wiley Post."

"This system better except for approaches which are within 10° of runway."

"The system compares favorably with the standard REIL."

NOTE: See Appendix for additional comments.



DATA REDUCTION

Model 1400 RAIL - Wiley Post.

Summary of questionnaires:

1. Does it provide you rapid and positive runway alignment information ?
YES - 40 NO - 0 NO COMMENT - 0
2. Did it assist you in making a safe landing when your final approach course was offset more than 15 degrees from the centerline ?
YES - 38 NO - 1 NO COMMENT - 1
3. Did it assist you in completing your circling approach ?
YES - 39 NO - 1 NO COMMENT - 0
4. Did you find any of the light configurations as being objectionable ?
YES - 18 NO - 22 NO COMMENT - 0
RAIL Only (Figure 3).....1
LDIN (Figure 4).....5
RAIL with Roll Bar (Figure 7).....4
RAIL with 3 Roll Bars (Figure 8).....4
High intensity or fast flash rate.....4
5. Does it override the preponderance of other surrounding lights ?
YES - 38 NO - 1 NO COMMENT - 1
6. What do you consider the best light configuration ?
LDIN - 1 RAIL only - 8 RAIL & roll bar - 4
Two parallel rows (not tested in project) - 1
RAIL with REIL - 26
7. What do you consider the minimum number of lights needed ?
FEWER THAN FIVE - 7 FIVE OR MORE - 31
8. Do you think the flashing rate is adequate ? (once per second)
YES - 37 NO - 2* NO COMMENT - 0
*when on high intensity or over 6 lights.
9. Do you think the sequence flasher time interval is adequate ?
YES - 34 NO - 4 NO COMMENT - 2
10. Did you find the sequence flashers blinding ?
YES - 6* NO - 34 NO COMMENT - 0
*When on high intensity at night.

11. What light intensity do you consider the best ?
 High day - 35 Low night - 37 Mixed - 1
 On pilot's request - 1 No comment - 4
12. Do you think the flash rate should be increased (Over 1 flash per second)?
 YES - 0 No - 40 NO COMMENT - 0
13. Did you encounter any spatial disorientation ?
 YES - 4* NO - 36 NO COMMENT - 0
 *4 subjects identified distraction, not disorientation.
 1 stated a need for runway lights.
 1 stated distraction due to LDIN.
 2 stated distraction due to roll bar system.
14. How does this compare with other RAIL systems you have flown ?
 Same as other systems - 4
 No previous experience or no comment - 12
 Need system with 2 parallel lines - 1
 Better system - 18 (Because of dimming and 360° feature)

DATA REDUCTION

RAIL/REIL System.

After the first 29 subjects had been recorded, a review of the questionnaires was made. Comments had been received that the RAIL with 3 roll bars (Figure 8) was too bright, so it was eliminated early. Other comments eliminated the LDIN system as unnecessary when lights have a 360° capability. It also was identified as giving one subject distraction. The next runs concentrated on RAIL, REIL, RAIL with REIL, and RAIL with roll bar. Special emphasis was also made on the best flash rate, and 9 extra questionnaires were recorded.

Summary of special questionnaire:

1. What flash rate did you like best on the RAILS ?
 Once per second - 9 Twice per second - 0
2. What flash rate did you like best on the REILs ?
 Once per second - 9 Twice per second - 0
3. Did either flash rate on REIL distract you on runup ?
 Aware of lights but not blinded - 1
 Twice per second much more distracting - 1
 No distraction - 7

4. What distance and altitude did you observe the REILs?
2 1/2 miles and 300 feet in IFR - 1 (Wx was 300/2)
Up to 8 miles in VFR night - 5
Up to 5 miles in VFR day - 2
5. What light configuration would you consider best for standard IFR approach system?
RAIL with REIL - 8
RAIL with REIL or roll bar - 1
(All preferred 1 per second flash rate)



DATA ANALYSIS

REIL, Model 1600 and 1600E.

Basic factors used in the evaluation of the 360° REIL systems from questionnaire responses were as follows:

1. Effectiveness in runway identification. (Items 1-6).
2. Intensity and flash rate. (Items 7, 8, and 10).
3. Spatial disorientation. (Item 9).
4. Effective altitude/distance. (Item 11).
5. Comparison with standard REIL. (Item 12).

The system effectiveness in runway identification and orientation was referenced by six questions, which resulted in 402 responses. Over 93 percent of the responses favored the system. Many comments favored the special advantage of having REIL indication in the 360° pattern, and considered this system superior to standard REIL for that reason. At the Expressway Junction site one end of the runway is in an area where freeway arc lights, city lights, and many other bright lights are located. The other end (north) is located where very little lights exist. The Wiley Post site is located so approaches could be made from the east over city lights or from the west over dark rural areas. The systems were very effective in runway identification under both conditions.

Intensity and flash rate were checked in several ways. After the first subject reported blinding effect on the Expressway Junction runway, subjects were asked to look at the lights, then try to read cockpit instruments. Over 98 percent found that they had no visual impairment. One observer walked out to within 6 feet of the lights, looked directly into the beam for several flashes, then found he could read his wristwatch without difficulty. One subject suggested increasing the output of the threshold lights. Nearly all subjects agreed that the once per second flash rate was far superior to twice per second. Where the system had intensity control (Model 1600), it was agreed that high intensity was desired during daylight operation, low intensity was much better at night.

No spatial disorientation was experienced by subjects. Runs at the Expressway Junction site were all made under VFR conditions, but 17 runs were made at Wiley Post under less than VFR. Both runways were equipped with edge lights.

Altitudes and distances at which the lights were effective ranged from 2000 to 5000 feet and from 8 to 15 miles at night in clear weather. Day values were 2000 to 3500 feet and from 3 to 7 miles. One pilot commented that he had overheard another say he had seen the lights from 35 miles out (clear weather at night). A few pilots who reported shorter distance visibility at night also stated that they were not out any farther but thought the lights would be usable at the greater distances.

In the comparison with standard REIL, 40 out of 63 subjects had flown into airports where standard REIL were installed. 32 comments indicated that the 360° system was superior to the standard system, primarily because of its being usable from all directions. The remaining 8 subjects indicated that the system was similar in effectiveness.

RAIL, Model 1400, also tested with REIL, Model 1600.

Basic factors used in the evaluation of the 360° RAIL and the RAIL/REIL in several configurations were as follows:

1. Effectiveness in providing runway alignment. (Items 1, 2, 3, and 5).
2. Possible spatial disorientation. (Item 13).
3. Intensity and flash rate. (Item 8, 9, 10, & 12).
4. Preferred configuration. (Item 4, 6, & 7).
5. Comparison with standard RAIL. (Item 14).

After the first 29 subjects had been recorded, questionnaires were screened, and, since the RAIL system with REIL was by far the most popular system, an addendum was made up for the questionnaire in order to determine:

1. Best flash rate.
2. Possible distraction on runup.
3. Distance and altitude observed.
4. Best configuration.

Effectiveness items resulted in 97 percent of the responses in favor of the system. Most subjects were in favor of the capability of the system to provide runway alignment information in all directions and the information it provided for a circling approach.

No spatial disorientation was experienced by the pilots. The four who responded other than negatively to disorientation questions admitted some limited distraction only. One pilot commented that the runway lights should be on (as they were in the tests). Three others were distracted when flying with the roll bar or LDIN system and the RAIL. These last configurations were eliminated as undesirable. One pilot remarked that when he looked back at the lights from southeast of the airport he experienced a mild visual effect. However, physiological phenomena of vertigo caused by turning the head to the side or rear have been demonstrated repeatedly, and may have no relation to lighting cues at all.

Intensity and flash rate questions show that 90 percent of the subjects thought intensity should be high in day operation and low at night. One suggested that the pilot control intensity so that he could call up the lights on bright when identifying the airport, then reduce intensity as he reached the final approach portion. The obvious danger of another pilot signalling high intensity callup while an aircraft is on final approach indicates the better desirability is to couple a photo-electric cell to the system so that daylight operation would be on high intensity and night operation on low. Of 40 pilots, 6 identified a blinding effect, all when the lights were on high intensity at night. The once per second flash rate was identified as most desirable in 95 percent of the responses. Pilot on-off control was recommended.

The configurations tested were as follows:

1. RAIL only. See Figure 3, Page 4.
2. LDIN. See Figure 4, Page 4.
3. REIL. See Figure 5, Page 5.
4. RAIL/REIL. See Figure 6, Page 5.
5. RAIL with Roll Bar. See Figure 7, Page 6.
6. RAIL with 3 roll bars. See Figure 8, Page 6.

Configuration 6, RAIL with 3 roll bars, was considered too bright by some, but mainly was considered to be confusing, by presenting a large 'blob' of light. It was therefore eliminated from the test in the early stages. The LDIN was visual reception occurred without any advantage from the offset lead-in light units; the 360° feature of the lights was very effective in circling approaches, and there was no advantage to offsetting the farthest out lights. Likewise, the RAIL with roll bar was dropped during the final runs when so few subjects considered it to be advantageous. Of the two remaining systems, RAIL was considered adequate by 8 subjects and RAIL/REIL by 26. 82 percent felt that a minimum of 5 RAIL lights and 2 REIL lights were necessary.

Comparison with standard RAIL system resulted in the following comments:

1. Same or similar to standard.....4
2. Not familiar with standard system.....12
3. This system better than standard.....18

One pilot suggested two parallel rows of RAIL lights as the best system.

Three responses suggested that the runway threshold lights should be increased in intensity. One of these was lighting expert C. A. Douglas, of the National Bureau of Standards. Mr. Douglas has been evaluating aviation lighting for many years and is considered one of the world's leading authorities on the subject.

ADDENDUM SHEET RESPONSES - RAIL/REIL System.

1. Flash rate - once per second.
2. Distraction on runup - only on fast flash.
3. Distance effective - to 8 miles, clear weather.
Altitude observed - 200 to 5000 feet.
4. Best light configuration - RAIL with REIL.

Optimum spacing of light units was evaluated on a number of flights. Distances between light units was varied from 150 to 300 feet. The optimum was agreed to be from 200 to 300 feet, with the closest fixture to the threshold set 300 to 350 feet out. The minimum tested, 150 feet, was found to be acceptable but marginal. When two lights were offset along the extended centerline to form irregular spacing, it was found that with 200 to 300 foot spacing one or two lights could be placed plus-or-minus 50 feet from their interval position without any visual problems developing, so siting difficulties can be solved in this way.

Low visibility weather conditions prevailed on several flight evaluation runs. In helicopter runs with low ceilings, the RAIL/REIL system was visible for 1/2 to 3/4 mile before the runway lights could be seen. On several runs in fixed wing aircraft the lights could be picked up at approximately 1 1/2 miles from the runway when visibility was 1 mile or less.

Video tape recordings were made of the systems as a means of reporting findings of this project. The RAIL/REIL was compared with the standard MALS/RAIL installation.

The RAIL portion of the MALS/RAIL system has a peak intensity of 10,000 to 17,000 candelas. Its minimum intensity across the full 25 degrees of beam width is 5000 candelas. One of the most discouraging features of the standard system is the fact that it is blinding to the pilot on final approach at night. For this reason, the system, when installed with MALS and HIRL, is wired so that the strobe lights will not turn on unless the MALS and HIRL are on the higher intensity steps. In comparing the standard system with the 360 degree system, the two step intensity selection eliminated the problem of too bright RAIL fixtures so that the entire MALS/RAIL system could be used at night in clear weather.





Figure 9. Shooting of Video Tape Project Report.

FINDINGS

REIL, Models 1600 and 1600B

In the course of this evaluation it was found that most of the subjects considered the 360° lighting systems to be superior to the standard REIL. The lights provide rapid and positive identification of the runway regardless of the position of the aircraft relative to the airport. They provide guidance during circling AND straight-in approach, and override other lighting.

No subjects experienced spatial disorientation attributable to the lights while flying the REIL.

There is no blinding effect on the Model 1600B. With the intensity setting high for day and low for night operation, the blinding effect on the Model 1600 is very minimal.

Night usable distances in clear weather are 8 miles or over. Day distances are approximately 5 miles.

RAIL, Model 1400 (and coupled with REIL, Model 1600)

Most subjects considered the 360° RAIL to be superior to the standard RAIL. The lights provide alignment for straight-in, offset, and circling approach. They override other lighting.

There was no spatial disorientation due to lights.

Blinding effect is minimal when lights are set to high intensity for day and low intensity for night operation.

Pilot control for on-off was usable. Intensity control might be better left to a photo-cel or other ground method.

Of configurations tested, the RAIL with REIL is the preferred system, with once per minute flash rate.

Optimum spacing between fixtures is 200-300 feet, with 150 feet minimum, with the first fixture located 300-350 feet from the threshold. A tolerance of plus-or-minus 50 feet in spacing distance is acceptable. No apparent problem exists when the lights are not on a flat plane out from the runway.

Lights are effective under low visibility conditions.

Increased threshold light intensity is desirable.

APPENDIX

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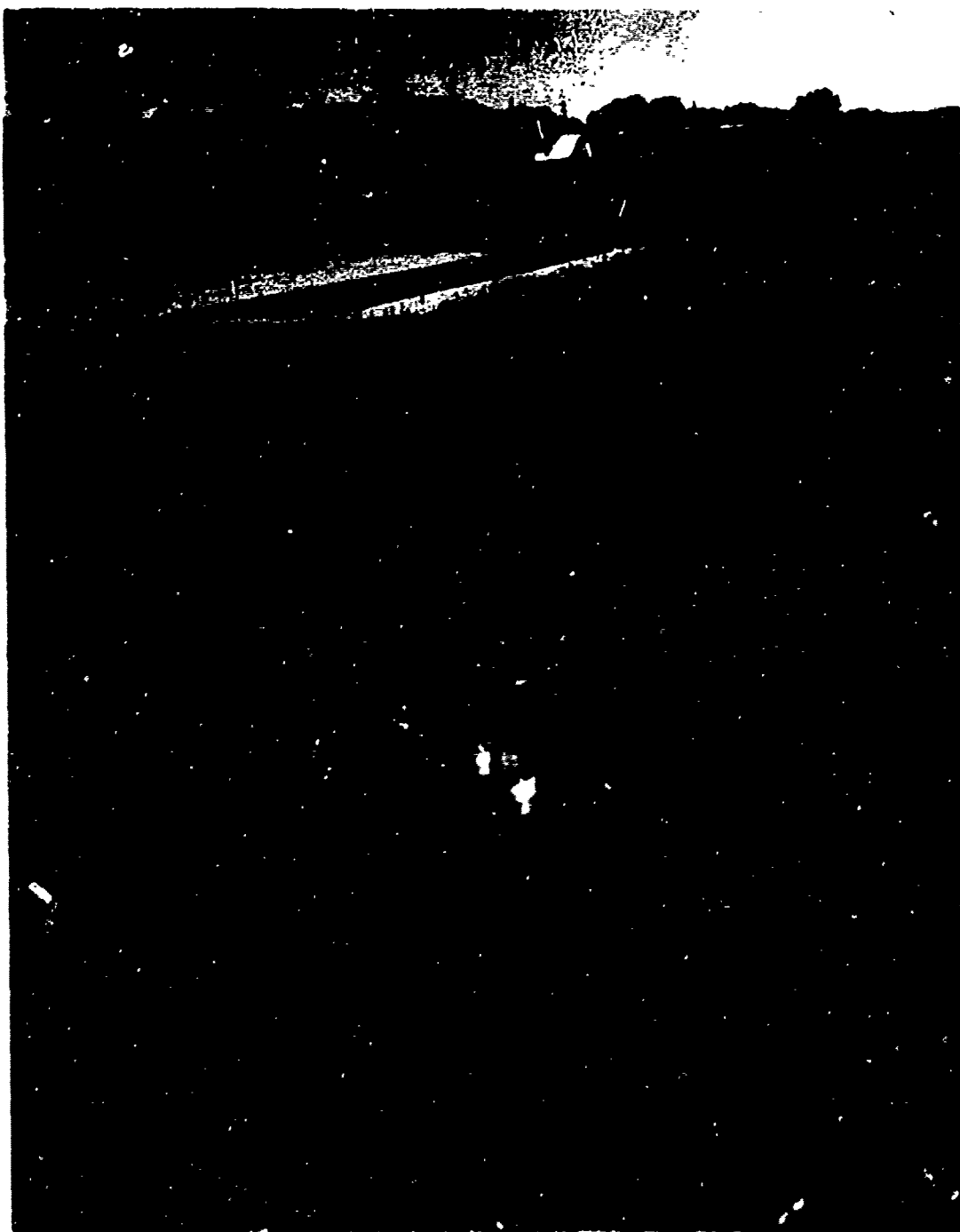


Figure 10. Model 1600B REIL Light.

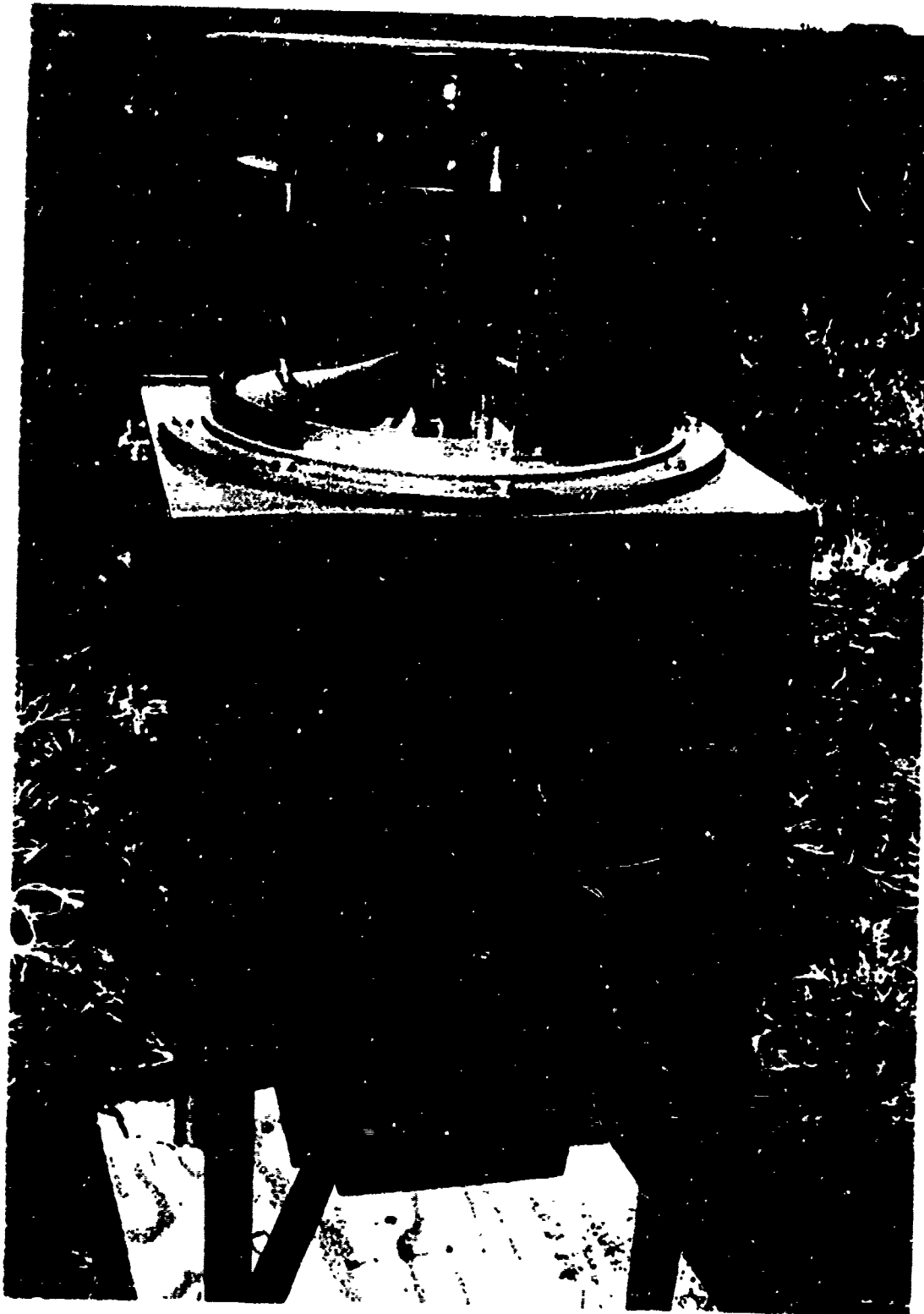


Figure 11. Model 1600 REIL Unit. (Same unit is used in
Model 1400 RAIL System)

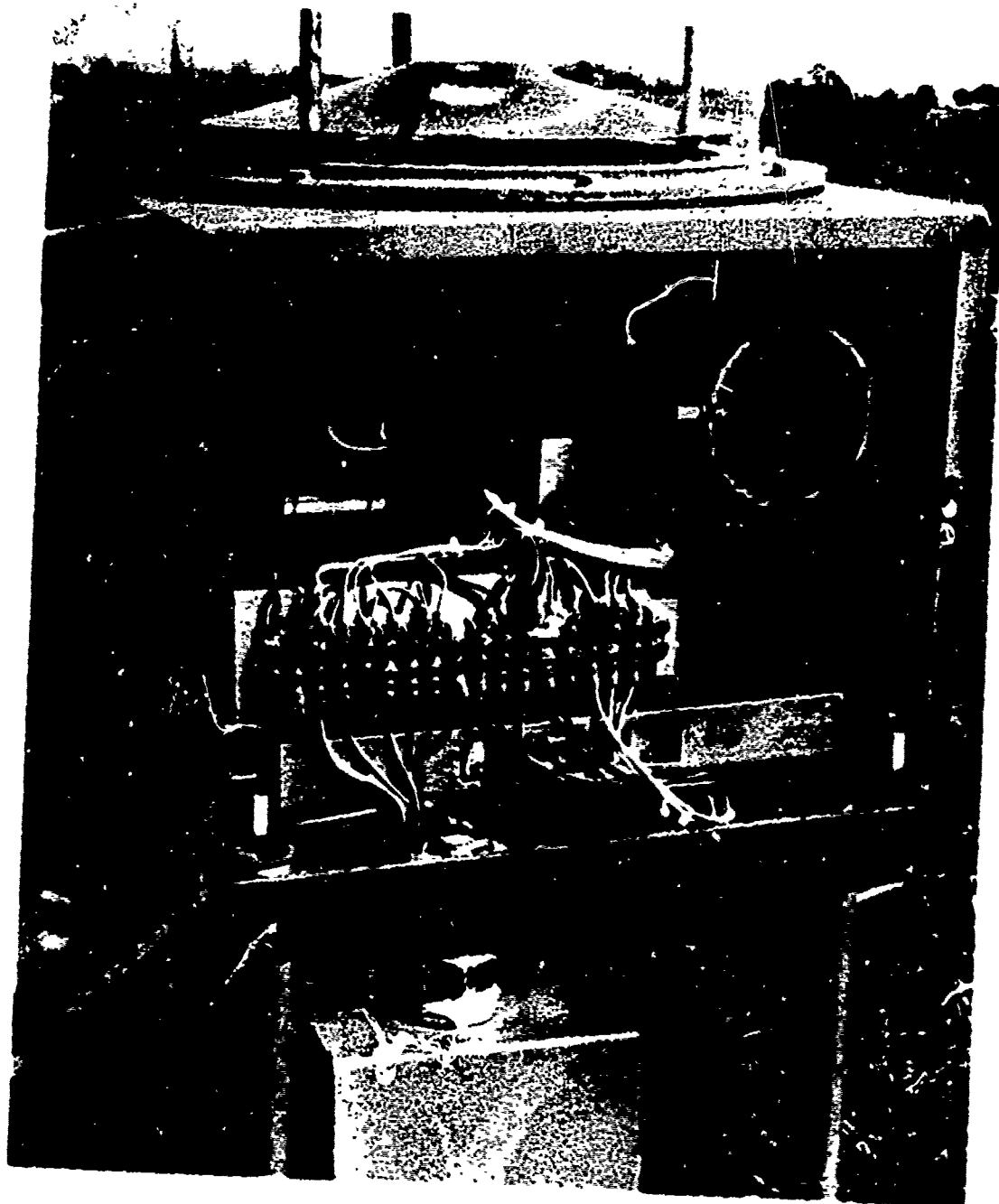


Figure 12. Interior of Model 140C RAIL Unit (1600 REIL).



Figure 13. L-854 Receiver - Controller.



Figure 14. Interior of L-854 Receiver-Controller
Showing Receiver.



Figure 15. Interior of L-854 Receiver-Controller Showing
Light Controls.



Figure 16. Model 1600 REIL Installed at Threshold.



Figure 17. RAIL System Installed on Extended Runway Centerline.



Figure 18. Sequencing Control Box Installation.

Subjects' Comments - Model 1600B REIL

Overall

"This system is very beneficial in locating the airport due to the surrounding lights and provided a visual fix for the threshold while flying the pattern."

Expressway airport has a very short runway and is located between the hills in a creek bottom. Therefore this type of lighting is very beneficial toward locating the airport and runway threshold."

"I felt the 360 degree strobe was very effective and especially at this airport and I feel the flash rate was very distinctive at its present rate."

"I found the lights to be helpful in lighting the active runway to the airport and they could be life-saving in smog or fast-closing weather."

"The 360 degree strobe system should prove very effective in reducing pilot workload for night landings at strange airports located in large cities (high aircraft density areas). This would allow the pilot to devote more time to traffic separation and aircraft control. I find that landing under the above conditions most of my time is devoted to trying to locate the airport often with limited success in spite of VOR radios and radar vectors. Orientation for downwind, crosswind, and base leg correction should be improved."

"A large Mobil gasoline sign was located on the turn from downwind to base leg and if this turn was made short and low it had a tendency to blank out the left REIL. However, it is questionable if this sign over-rode the REIL."

"Due to the low intensity of the runway lights and the excessive amount of freeway as well as the bypass light and other lights such as motel, service station, restaurants, etc., it is very difficult to locate the Expressway airport and direction of landing. The 360 degree strobes are a welcome aid toward locating the airport and the runway threshold especially in the existing confusion of light at this airport."

"360 degree much more effective in quick location of the runway threshold and general location of the airport."

"I found the lights to be more noticeable at a distance rather than close-in during daylight hours."

Flash rate.

"The flash rate of 1 per second seems superior to the 2 per second standard. The slower rate is not so frantic. Based on this observation I would be willing to endorse this configuration and flash rate over the existing standard. A departure was made from the opposite end into the lights and no blinding effect was noted."

"From previous experience with strobe lighting, I believe the rate could be increased and the intensity reduced and the effect would be just as good. However, also from this previous experience the strobe may be an irritant to nearby residences at night, and the increased rate would worsen the irritation factor."

"A faster flashing rate may be of some assistance in locating the airport when located on the approach end of runway 02, due to the preponderance of other surrounding lights. However, faster flashing rates could cause student or low time pilots to increase their airspeeds on the final approach and possible emotional upset to some if increased above the two flashes per second rate."

Intensity.

"The flash rate is sufficient to catch your attention and not so much as to blind you on taxi, rump, and approach."

Parked 30 feet from the strobe light, looked directly at the light for 5 seconds, then read the numbers on the fuel flow meter (small numbers) in the cockpit without difficulty."

"Lights were not blinding as such, but were in a small way disconcerting, especially as this was my first time in making an approach to this system. After familiarization, distraction would, I feel, be eliminated."

"Was not blinding, but did seem distracting on final approach." (This pilot emphasized the REIL's help in finding the airport).

"This system is not blinding and is visible from all angles. The flash rate is recognizable from a distance well beyond that which might be considered usable. I prefer the system over the now accepted standard."

Subjects' Comments - Model 1600 REIL

Overall

"These REILs do not differ from most REILs except they are visible from the "back" at a lower than normal intensity. They are not objectionable and give a strong (demanding) attention to the runway end and width of the runway. They are extra effective when combined with the RAIL."

"Airport orientation from any direction is greatly improved. Other than that I see no difference from other REILs at other locations."

"On an actual low visibility approach I was able to identify the runway almost immediately. Also on the CAVU flight the runway end was in sight from every direction and I was able to immediately distinguish the REILs from the city lights. During taxiing and also waiting for takeoff I looked at the strobes for a few seconds and then into the cockpit and was able to read the instruments with no trouble at all."

"This omnidirectional system is excellent for acquisition and identification of airfield in a circling approach situation. For an inexpensive installation at a general aviation field it will provide an excellent improvement over existing low visibility lighting installations. The feature for generating the system from the air will prove invaluable for unattended airfields."

"No approaches made during reduced visibility, but feel it would be definite help. Definitely better than standard system."

"Omni-directional REIL is very useful for initially acquiring the airfield/duty runway. This is especially true when surrounding/lighting patterns mask and/or resemble the runway lighting."

"I feel this should be helpful in uncontrolled airports where both IFR and VFR approaches are made."

"Would there be objections from airport neighbors (the non-flying neighbors) to the brilliance of these lights?"

"The REILs were effective for aligning the aircraft and identifying the runway."

"The maximum distance I was away from the airport was 8 miles at 3000 feet and I feel they could have assisted me in locating the airport much further away at this altitude."

"Airport orientation from any direction is greatly improved, other than that I see no difference from other REILs at other locations."

"I feel that aviation safety would certainly be enhanced with a set of REIL lights at the end of each runway."

"Might be better if beam alignment with the runway was more definitive as with standard REIL. Very satisfactory for low cost small airport locations."

"No chance to try low visibility evaluation, but should be definite assist."

"These conditions (low visibilities) did not exist during this flight, but I feel had low visibility been present these lights would have helped. At night only, these lights were somewhat blinding during runup."

"Overheard another pilot state that he observed the lights when 35 miles northeast of PWA. Did not state altitude."

"The standard REIL is not visible from all directions and is not as good for locating an airport and runway. They help to maintain visual contact with the end of the runway during a circling approach."

"Better during circling maneuver, no difference on final."

"Believe it advantageous to have runway end identification for 360° as compared for example with the REILs installed at Will Rogers World Airport, Runway 12."

Flash rate

"Much better for locating the runway. I think the strobe rate should be reduced, not increased. The lights are a great help in airport locating."

Other lights

"Recommend the threshold lights intensity be increased. I could not see them until I was directly over them, and they could be a valuable assist in providing roll guidance."

Intensity

"Lights should be shielded so as to protect pilots eyes when at runup position."

"There was no blinding from the lights even with continued observation of the lights. The aircraft instruments could be read clearly."

"The lights should be shielded more in the direction of the taxiway-runup area by using a prism arrangement."

"The REIL lights could be toned down during the final segment."

"No problem reading small print in cockpit after staring at lights."

"Lights seem quite bright, but do not disturb night vision or near vision capability."

"Did not override runway lights, but is more prominent than all other lights."

"I made an effort to impair vision by staring directly at the lights. There was no impairment."

"Annoying when stared at but not blinding. When I was concentrating on the runway the lights were not annoying."

"Very distracting at night when on high intensity."

"Although the REILs were considerably brighter than any surrounding lighting it didn't appear to distort my vision."

Subjects' Comments - Model 1400 RAIL

Overall.

"Overall impression very good. 360° visibility feature is excellent."

"I thought it was easy to identify the runway, and thought it would stand out even when there were many other lights in the vicinity of an airport."

"This system is readily identifiable and should prove to be a boon to aviation. It should prove invaluable for orientation during low visibility circling approaches. In fact, with the use of this system the offset angle that presently defines a straight-in approach could possibly be increased."

"I wonder if the 360° feature might be disconcerting to pilots at other fields. What would be the results if similar RAILS were installed at other airfields in the same area?"

"On the circling approach I was guided directly to the approach end of the runway."

"This lighting system indicates progress, and I found them extremely helpful not only for an approach aid but for airport identification, runway orientation, and a very useful guide to visual height above the ground on final approach."

"It is very helpful in picking up the runway approach from any direction and from a considerable distance away."

"The omnidirectional feature greatly improves the acquisition of the field on circling or low visibility approaches when final approach course is not consistent with the landing run-

Disorientation

"While looking back at the lights (RAIL) on a 215° heading from the field (over Lake Overholser) the sequence of the lights appeared to give a rocking chair effect. This may be peculiar to me only but since we have had, within the past year or so, a fatal Queenair accident at PWA as the result of disorientation, the possibility of ground light induced vertigo should be considered during circling approach."

Configuration

"RAIL/REIL reduces the effort required to initially acquire the airfield. Once visually acquired, use of the lights provides an easy method for runway alignment. (Circling or straight-in)."

"Looks like a very promising system with 6 (RAIL) and 2 (REIL) configuration. I doubt that less than 6 lights would be very effective."

"By combining the two systems you can tell which end of the runway the lights are on before you can see the runway."

"Under the conditions (VFR) RAIL wasn't all that important. I can see that it might be another matter under marginal or IFR conditions."

"Suggest consideration be given for use of 6 light RAIL as replacement for C & G airport beacon."

"REIL only is minimum lights for VFR and RAIL is minimum for IFR approaches. The best configuration is to have both RAIL and REIL systems to be better oriented throughout any kind of approach."

"In using the complete system, the fact that the REILs are located outside the lines of the RAILS (This is the FAA standard) gives an explosion illusion at the RAIL location. In flying the project I wondered why they were not on a straight line."

"The full configuration (RAIL with 3 roll bars) is too much and does not give a good intuitively correct pattern."

"I felt that the directional advantage of the system was lost using the side lights of the RAIL system until the last ½ mile of the approach. This was especially true with the lights on bright." (Reference to RAIL with roll bar).

"I found none of the lighting really objectionable, but System 5 (RAIL with roll bar) on high intensity under clear conditions was a little much."

"The wing bars did not help me and provided too much and too many lights."

"The t-bar could be confusing and does not add any appreciable lateral orientation - in fact at angles foreshortening could give you an erroneous impression."

"No advantage and some possible confusion of roll bar w/RAIL."

"I felt that my approach would not be affected by the "guide-in lights (LDIN) once I am close enough to identify the guide in effect.

"I feel that all lights should be in a straight line with the runway."

"The LDIN would probably cause some disorientation due to the motion created by the effect of the last two lights."

"The RAIL is excellent for runway orientation during circling approach. The pigtail (LDIN) is nice to have but distracting on a straight-in approach."

"I did not like the straight in approach with the full system operating including the circling approach lights (LDIN). It gave the feeling of losing some runway alignment accuracy."

"Lead in lights are not useful in their present position. They are too close to the end of the runway. I believe they would be beneficial in their present location only for very low speed aircraft (60 mph final approach speed)."

"A low time pilot may bank too steep during a circling approach with an adverse wind. This concerns the bent area of two lights when making a VOR 1 circling approach." (LDIN)

"Angle of offset lights for circling approach seems too sharp - they should not be more than 30 degrees." (LDIN)

"I do not believe the dogleg is necessary that was used on the VOR 1 approach."

"Do not feel the 3 additional lights provide an adequate test for circling patterns - consider expanding to minimum 6."

"I do not think the additional 3 offset lights were much help under good visibility conditions. I preferred the straight line configuration."

"The curved tail signifying pattern direction greatly enhances down wind set up to final approach."

"The lights helped to find runway but lead-in effect was missing due to too short a system - if anything a little distracting due to apparent artificial horizon established by the angled lights." (LDIN)

"Excellent system, especially the curved leadin for approach opposite landing direction. Good alignment information from all quadrants. Good roll guidance from 3 light bar, but not necessarily for most applications."

"I noted no advantage and some possible confusion from LDIN."

Flash rate

"There should be time between last light off and first light on so the pattern will not run back and forth."

"The system was not improved significantly by increasing the flash rate from 1 per sec to 2 per sec, and the 2 per sec flash rate is more annoying to ground operations."

"Also the faster flash rate of the two settings appeared best to me."

"Light intensity by pilot's request."

"Should be a little longer time between flash sequences to reduce the bouncing back and forth appearance presently produced by the flash sequence rate." (2 per sec)

"I experienced some problem with the reduced flash rate when the light intensity was low and the roll bars on."

"At the existing rate (1 per sec) and delay between the last RAIL and the REIL there is no tendency for the direction of the strobe run to reverse itself."

"The fast pulse rate at a distance or at low altitude appears as a centerline REILs light alternating in pulse cycle and to me is also objectionable. In fact on a circling approach with fast pulse rate I found myself watching the light. On slow rate I observed a whole picture concept with no apparent effort on my part."

"The 1 per second flash rate with one light delay before the REILs fire is very effective. It is not annoying to watch, clearly identifies the runway end, and on straight in approach provides some roll guidance when the REILs fire."

"The flash rate and sequencing seem that both could be slower in this pilot's opinion."

Other lights

"Would say it is mandatory to also have the runway edge light operating."

"Threshold needs beefing up. Suggest the addition of 6 or 8 200 watt elevated approach lights as wing bars." cad.

Intensity effect

"I didn't notice any blinding effects of the lights on the low approach."

"Blinding with too many condenser discharge lights near the threshold plus REIL lights. The REIL lights could be toned down during the final segment."

"I stared at the lights for 6 or 7 flashes, then immediately read small print in the cockpit with no problem."

"Also, flashers should be shielded to provide protection at runup position."

"During taxi and runup the strobes were blinding. They should be shielded from ground level in the taxi and runup areas."

"At night I believe low intensity setting would be best, however under limited visibility and weather conditions this may not be so."

"When set on bright intensity, the flashers are almost too bright as the boundary is reached. No problem on low intensity."

"Maybe excess light close in even on low setting - possibly do not need as many of the roll bar lights." This flight was flown on 3 roll bar system.

"The flashers were very blinding on night landing over approach end with all burning even in low position." (Reference is to RAIL with 3 roll bar configuration which was eliminated early in the test series).

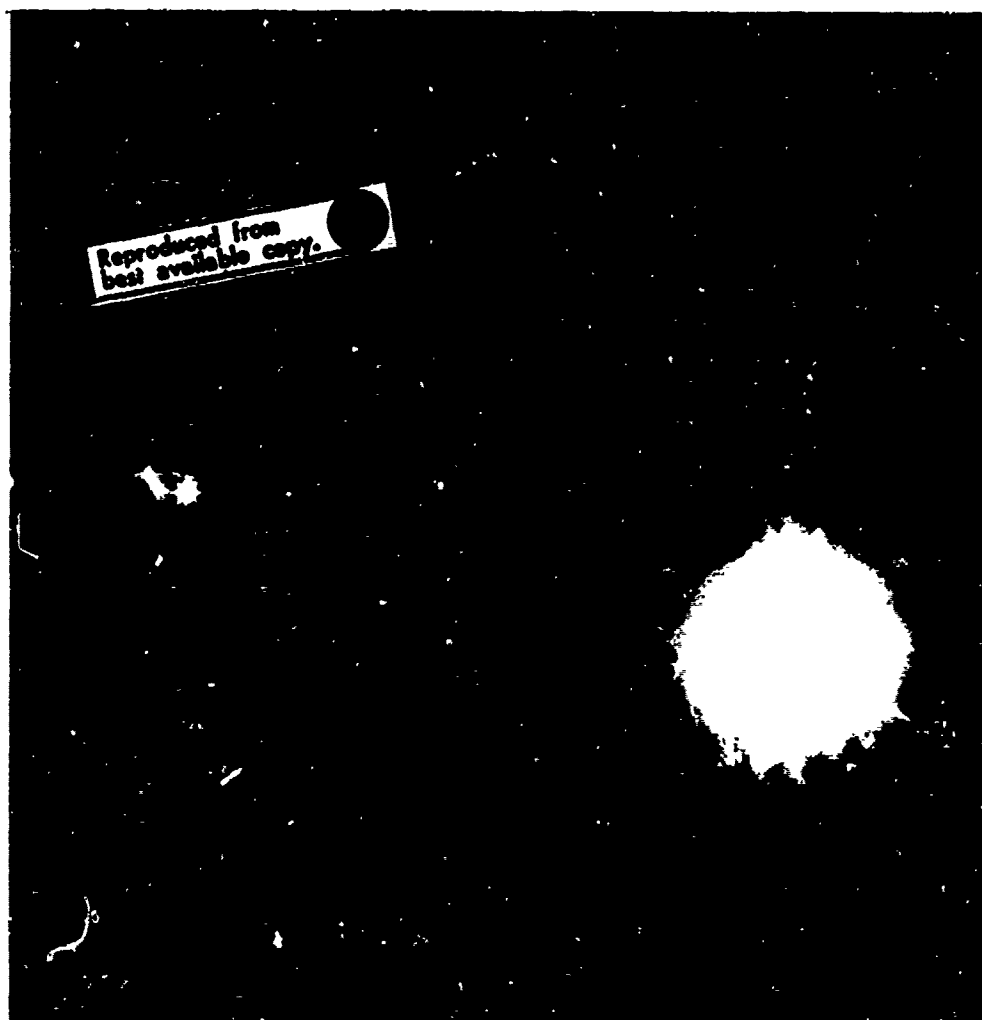
"High intensity on the RAIL blanks out the sequence effect."

"With all lights operating, I had an overwhelming urge to pitch the nose up. I feel this may be due to light reflection from the ground."

"Believe we have to have high intensity for scud or low ceilings on instrument day conditions. Do not know about night as not observed."

"The intensity is very important and should be adjustable to conform to the degree of darkness and the prevailing visibility."

"The only derogatory comment I can make about the lights involves having all the RAIL and REIL lights going while the pilot is in runup pad on the airport. It was no more than a confusing display of fireworks which resulted in some uneasiness or discomfort. However, it might be disquieting to a novice pilot unfamiliar with the purpose and benefits of the lights. There were no ill effects on my night vision either on the ground or in the air."



EXERPT FROM ICAO DOC 7920-AN/ Part 4
AERODROME MANUAL
Visual Ground Aids

CHAPTER 2 - APPROACH LIGHTING AND MARKING

2.1 Circling Guidance Lighting

2.1.1 Lighting for circling guidance is required primarily to assist the pilot in manoeuvring the aircraft and positioning it for a landing on a runway which may not be clearly in view because of reduced visibility and/or ceiling. Typical conditions of cloud base and meteorological visibility under which large jet aircraft could execute a circling approach are in the order of 200 m (600 ft) and 2 NM and for smaller propeller-driven aircraft currently in use in the order of 120 m (400 ft) and 1 NM. However, in providing lighting for circling guidance under these minimal conditions, consideration should also be given to the value of such lighting in facilitating manoeuvring under visual contact conditions and thus expediting the flow of traffic at high traffic density aerodromes. In this situation the aircraft may begin its downwind leg at a height of 300 m - 500 m (1 000 - 2 000 ft). The most usual circumstances under which pilots find adequate circling guidance to be lacking are in daylight haze conditions, and a lighting system which is found to be suitable under these circumstances will also be satisfactory (after suitable control of intensity to avoid dazzle on final approach at night) for the lowest conditions of visibility and ceiling under which circling approaches are likely to be conducted by day or by night.

2.1.2 To be satisfactory, a circling lighting system should provide the following elements of guidance:

- (i) Adequate indication of the position and alignment of the landing runway. This facilitates the positioning of the aircraft on the downwind leg at the desired distance from the runway, and enables the pilot to detect and compensate for tracking errors.
- (ii) A distinct indication of the landing threshold, so that a pilot can determine when he is abeam of the threshold.

Timing procedures employed by pilots, under visual contact conditions, to position the aircraft on final approach at a suitable distance from the runway threshold, require accurate knowledge of the position of the threshold.

- (iii) Adequate lighting along the extended runway centre line in the direction of the approach and compatible with the threshold indication.

2.1.3 In order to have alignment guidance a pilot needs to see approach lights, runway alignment indicators or approach light beacons or runway lighting or marking. In this connexion, consideration should be given to the possibility that, where traffic density is high, aircraft may be required to extend the downwind leg to a greater distance than is operationally necessary in order to establish adequate separation from other landing aircraft. Under these circumstances, the provision of additional alignment guidance along the runway extended centre line will be desirable to a correspondingly greater distance from the landing threshold. The addition of runway alignment indicators or approach light beacons would also provide useful guidance of aircraft conducting straight-in approaches.

It is desirable also that the method used to identify the threshold should provide as much roll guidance information as possible. Where adequate roll guidance (e.g. in the form of a simple approach lighting system) is otherwise absent, provision of this guidance in the threshold area for final approach is essential.

2.1.4 Fig. 2-1 illustrates the approximate dimensions of typical circling approaches and will indicate the azimuths, elevations and areas throughout which the system should provide visual guidance.

2.1.5 Fig. 2-2 illustrates a system of circling guidance lights.

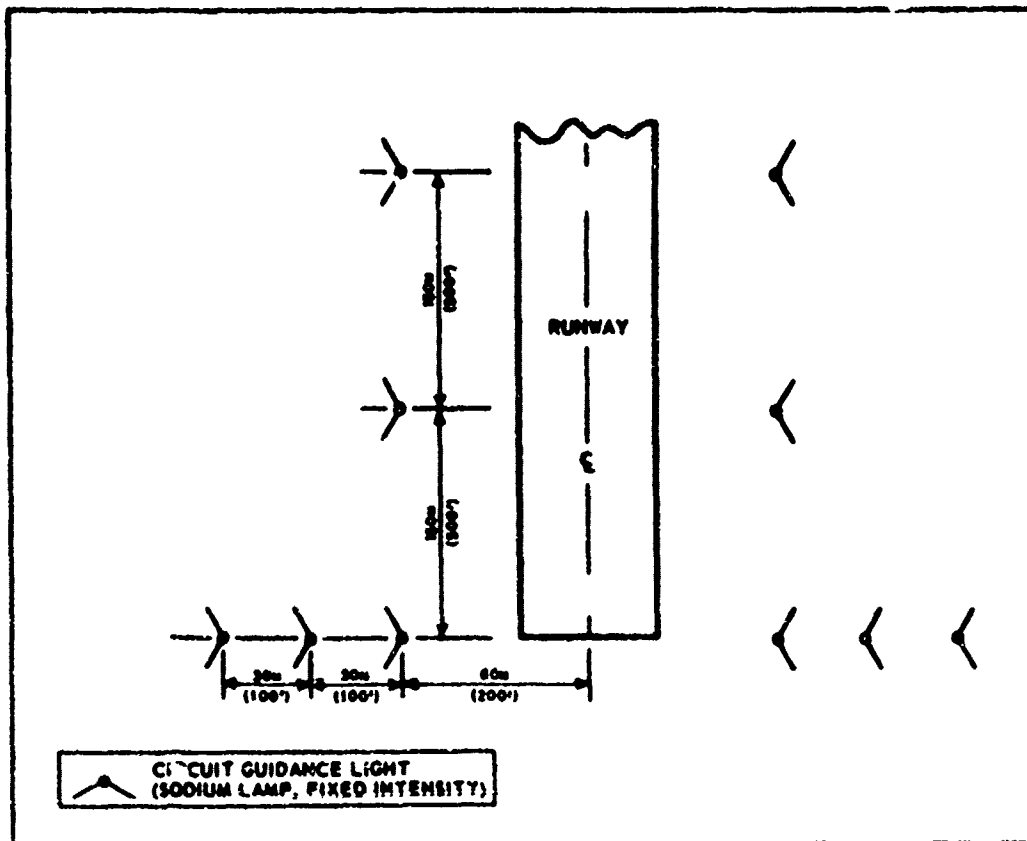


Fig. 2-2.- HIGH INTENSITY CIRCUIT GUIDANCE LIGHTING SYSTEM
AS PROPOSED FOR NON-PRECISION APPROACH RUNWAYS

2.2 Runway Alignment Indicator

2.2.1 The dimensions of the pattern flown by an aircraft making a visual circuit depend largely upon the aircraft's size and speed. The dimensions associated with the large turbo-jet aircraft are so great as to discourage this landing technique even on runways not equipped with precision approach radio aids. There is a tendency, in such cases, to use some form of navigational radio aid to align the aircraft as accurately as possible with the runway, and then make a straight-in approach. Depending upon what radio aid is available, and other factors such as obstacles in the approach area, the critical height for such operations may be anything from about 120 m (400 ft) to 240 m (800 ft) or even more. This means that for a $2\frac{1}{2}^\circ$ approach angle, the aircraft will reach critical height at distances varying from about $1\frac{1}{2}$ NM to perhaps more than 3 NM from the runway threshold. Under these circumstances, therefore, it is of little significance whether the approach lighting pattern is $\frac{1}{2}$ NM or $\frac{3}{4}$ NM long since the basic requirement in restricted visibility conditions is for the necessary visual information to be available from positions on the ground much further out in the approach. The information which the pilot needs on first making visual contact under these circumstances is, first, distance from threshold, secondly, approximate height and thirdly, a sufficiently accurate indication of his lateral displacement to make a correction of the right order of magnitude and finish with the aircraft on a heading substantially that of the runway.

2.2.2 This information cannot be given by a single beacon on the extended centre line of the runway, and not very well even by two such beacons. What is needed is a multi-light array such that the pilot can obtain the necessary positional and displacement information. Clearly, the lights must have an adequate lateral coverage to allow for moderately large navigational errors; they must also have the maximum intensity consistent with acceptable cost. An arrangement comprising seven lights which is still being assessed, is shown in Fig. 2-3.

